POWER WALKER

School of Engineering Sciences – Burnaby BC
vchoubey@sfu.ca

16 March 2015

Dr. Andrew Rawicz
School Of Engineering Science
Simon Fraser University
Burnaby, Canada
V5A 1S6

Re: ENSC 440/305W Design Specification for an Energy Harvesting and Storing System

Dear Dr. Rawicz,

Please find enclosed a copy of our design specification for an Energy Harvesting and Storing System. The goal of POWER WALKER is to produce a renewable source of energy by means of walking. For our proof of concept POWER WALKER aims to generate enough energy to run low-power electronics such as LED lights and simple radios. In addition, in the future we hope to generate enough power to charge an ordinary cell phone. This document contains the design specifications necessary for our product as well as a test plan to ensure safety, reliability and comfort.

The design specification provides a detailed description for all technical aspects of the product. This document also includes multiple charts and diagrams to further describe the different development stages of the product, along with the methods and procedures that will be used to test the different components. Our team will use this document, throughout the completion of the project.

Our team of senior engineers who are dedicated to this project include: Pouya Aein, Shelvin Chandra, Vani Choubey, Tommy Lu, Shervin Mirsaedi and Arshit Singh. We are ecstatic to work on this project and hope you share the same enthusiasm. We look forward to your support over the term and if you have any questions or concerns, please contact us via email at vchoubey@sfu.ca.

Sincerely,

Arshit Singh
Chief Operating Officer
POWER WALKER

POWER WALKER

A Functional Specification for Energy Harvesting and Storing System

TEAM
Pouya Aein
Shelvin Chandra
Vani Choubey
Tommy Lu
Shervin Mirsaedi
Arshit Singh

CONTACT PERSON
Vani Choubey
vchoubey@sfu.ca

SUBMITTED TO
Andrew Rawicz – ENSC 440W
Steve Whitmore – ENSC 305W
School Of Engineering Science

DATE ISSUED
March 16, 2015

Executive Summary

"Invention is the most important product of man's creative brain. The ultimate purpose is the complete mastery of mind over the material world, the harnessing of human nature to human needs." – Nikola Tesla

In this modern era of technology, a source of portable energy is crucial to stay connected with others around you. A dead cell phone battery equals a loss of productivity; you would not be able to check your messages, access social networking websites, or make an emergency phone call. At POWER WALKER our objective is to provide a portable source of energy in the event of an emergency.

POWER WALKER's SolexPRO will be the next "step" in renewable energy. This device is intended to generate electricity simply by walking. SolexPRO uses a customized version of solenoids built in house. As the user walks, the magnet inside the solenoid moves up and down which effectively converts kinetic energy into electric energy. The power that leaves the solenoids is in Alternating Current (AC) form. That power is then passed through a rectifier which transforms it into Direct Current (DC) form. This DC power is then used to charge a lithium-ion battery pack. In an emergency this battery pack can be removed and used to run low-power electronics such as LED lights and radios.

The ultimate goal at POWER WALKER is to be able to charge a cell phone battery using this system. In addition, an LED notification system will be added to display the charge percentage of our battery packs.

The team will follow all the design requirements in this document. This document contains the design specifications for SolexPRO. These specifications will outline and define various aspects of our device, including the Energy Harvesting Unit (EHU), Energy Storage Unit (ESU) and Energy Dissipation Unit (EDU) / User Interface Unit (UIU). It will also include test plans to ensure safety, reliability and comfort.

Table of Contents

List of Figures

List of Tables

Glossary

A	- Amps
AC	- Alternating Current
cm	- Centimeter
DC	- Direct Current
EDU	- Energy Dissipation Unit
EHU	- Energy Harvesting Unit
EMF	- Electromotive Force
ESU	- Energy Storage Unit
lbs	- pounds
LED	- Light Emitting Diode
mm	- Millimetre
PCB	- Printed Circuit Board
USB	- Universal Serial Bus
V	- Volts

1 Introduction

Power Walker believes there is a great potential in harvesting green energy for personal use. The company's goal is to harvest reusable energy from an average person's everyday errands. Our product SolexPRO aims to harvest kinetic energy that comes from walking. This product converts mechanical energy from the motion of the feet to electrical energy which is stored as electrical potential in batteries. Originally two prototypes were designed, SolexPRO E which was based upon an electrical system and SolexPRO F which was based upon a fluid system. Due to the low output produced by SolexPRO F, POWER WALKER has chosen to only proceed with SolexPRO E. Therefore, we have rebranded our product name to SolexPRO.

1.1 Scope

The scope of this document is to outline the design requirements of POWER WALKER's SolexPRO energy harvesting shoes. The specifications in this document fully describe the design specifications of our proof-of-concept prototypes and will serve as a basis for future iterations of the products. This document will also provide a development test plan that will be used to ensure the shoes meet product requirement and safety standards. Moreover, these requirements carry out the system overview and product design.

1.2 Intended Audience

The Design Specification is written as a guideline for the design and implementation of the SolexPRO. It is intended for use by all members of Power Walker. The team should refer to this document in every phase of development to ensure that the prototypes meet the predefined technical requirement.

2 System Overview

The SolexPRO system consists of multiple independent stages that are shown in Figure 1. In the following sections of this document the different stages are broken down and discussed in more detail.

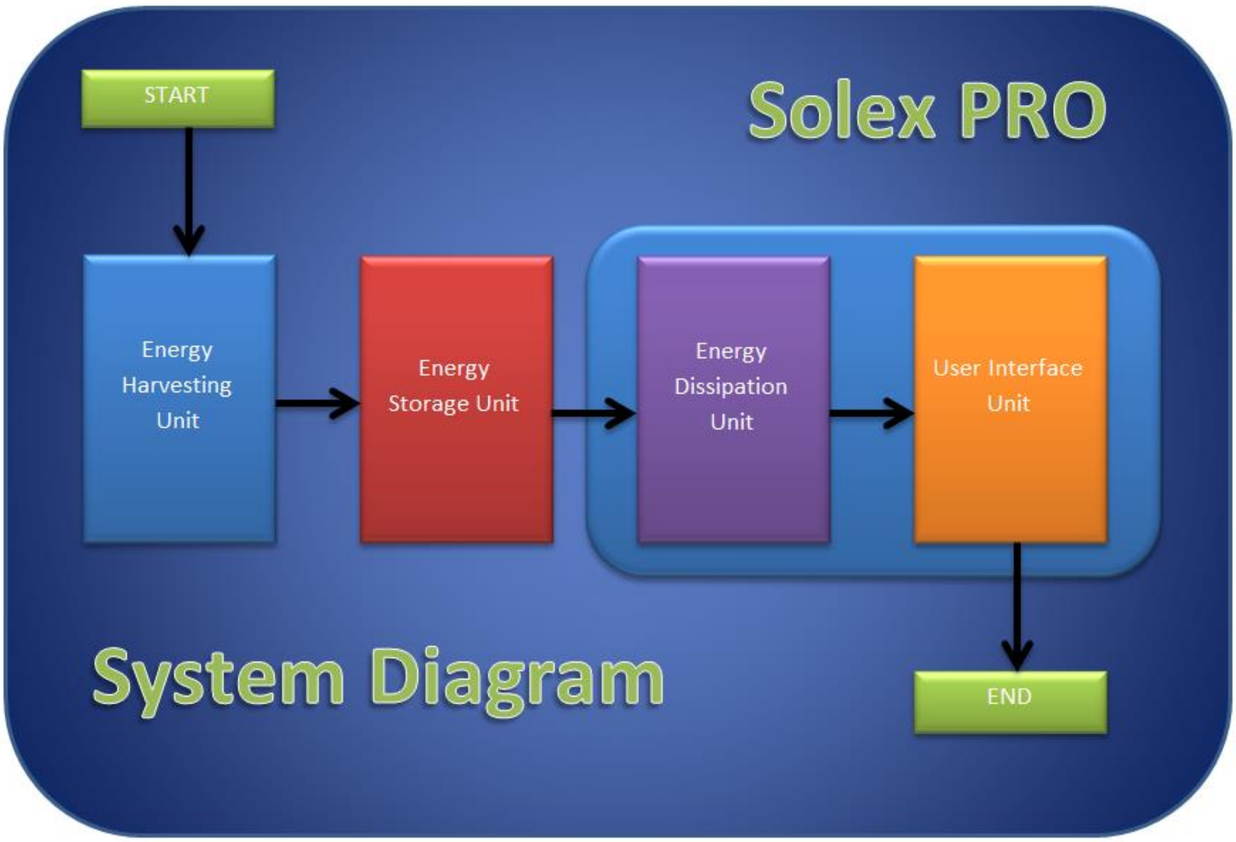


Figure 1: High-level SolexPRO System Diagram

The SolexPRO system consists of three primary blocks; the Energy Harvesting Unit (EHU), the Energy Storage Unit (ESU), the Energy Dissipation Unit (EDU) / User Interface Unit (UIU). The EHU converts kinetic energy from walking into AC power through the use of solenoids. The ESU rectifies the AC power into DC and stores that power in a lithium-ion battery. The EDU decouples the battery from the shoe that further allows the user to conveniently charge any compatible device through the UIU. Figure 2 below shows the Solid Works representation of the system.

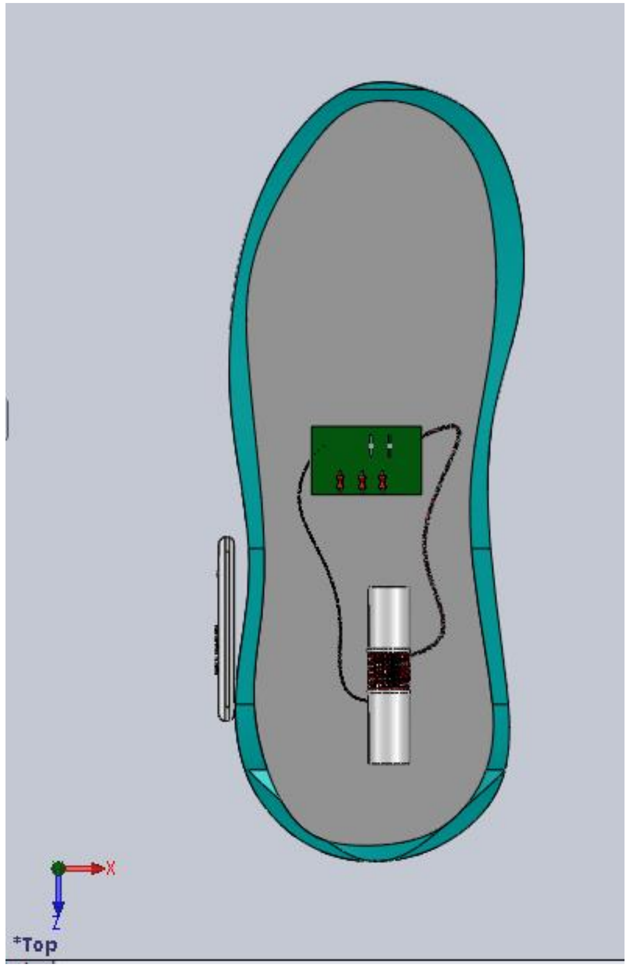


Figure 2: Solid Works Representation of the SolexPRO

3 Energy Harvesting Unit

3.1 Background

In SolexPRO, the Energy Harvesting Unit (EHU) converts the walking motion of the user into electrical energy by the method of electromagnetic induction. As the magnet moves inside a solenoid it from a gait action it produces an Electromotive Force (EMF). This EMF acts as an input to the Energy Storage Unit to further be used to charge electronic devices. The working of the EHU is based on the following process chart shown in Figure 3.

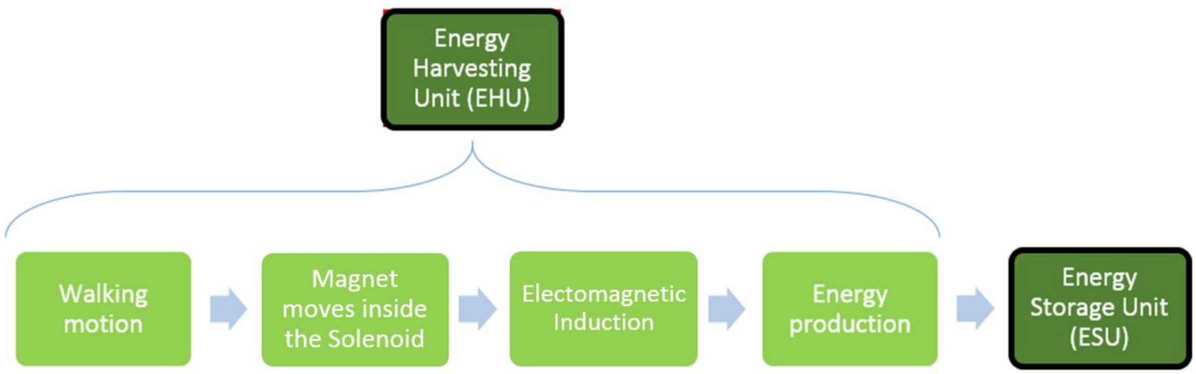


Figure 3: EHU Process Chart

The EHU is designed in such a way that structural integrity of the shoe is maintained, comfort to the end user is uncompromised and the viability of the design is both effective and efficient as noted in Functional Specification [R49-1] and [R50-2].

3.2 Physical Design

The solenoids used in the prototype are manufactured in – house. A Solid Works rendering of the solenoid is shown in Figure 4.

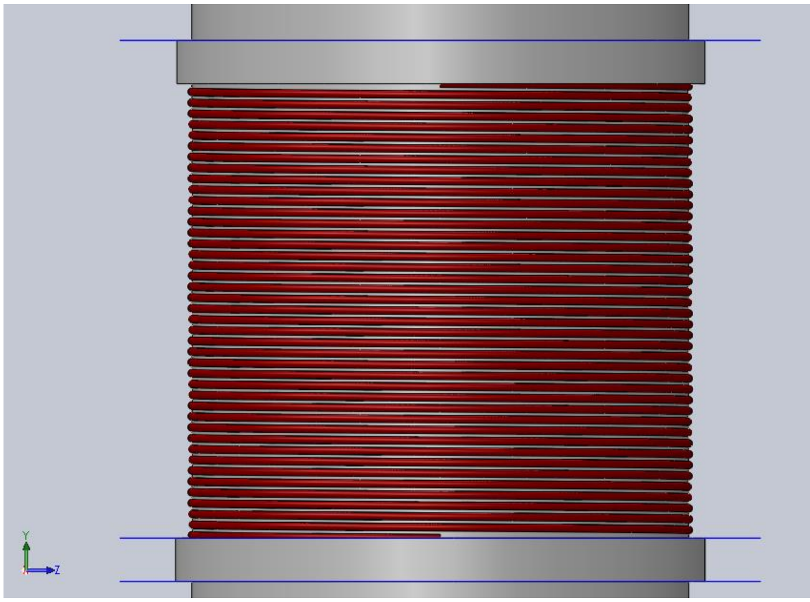


Figure 4: Solid Works rendering of Solenoid

The solenoids are designed according to the specifications outlined in the Functional Specifications. [R47-2] to [R59-1]. These specifications are listed in the Table 1.

Table 1: Physical Specifications of Solenoid and Magnet

Solenoid Length (mm)	210
Solenoid Diameter (mm)	210
Magnet Diameter (mm)	200
Magnet – Solenoid Offset (mm)	10
Magnet Displacement (mm)	1000
Number of turns	2500 ± 10%
Type of Wire	34 gauge copper wire

The numbers of turns used are based on the Equation 1 [1]:

$$B \propto \frac{I \times N}{l} \qquad \text{Equation 1}$$

Where B is the magnetic field strength, I is the current flowing through the solenoid and N is the number of turns and l identifies the length of the solenoid. Therefore, it is concluded that the magnetic field strength is directly proportional to the number of turns due to the fact that increasing the length of the solenoid is not viable due to design limitations. Therefore increasing the number of turns is the only approach to ensure efficient current production.

Electromotive force (ε) produced with this solenoid can be calculated using Equation 2 [2]:

$$\varepsilon = -\frac{\Delta(B \times A \times N)}{\Delta t} \approx V \qquad \text{Equation 2}$$

Where A is the Area of the solenoid, B is the magnetic field strength, N is the the number of turns and V is the potential across the terminals of the solenoid. Furthermore using Equation 2, efficiency factor is increased in our design by use of high number of turns and low resistance wires to minimize internal resistance [R58-1].

Functional Specification [R48-2] states the need to encase the solenoids. However, it has been decided to use horizontal arrangement of solenoids instead of a vertical arrangement. Additionally a hydrophobic [R49-1] spray is used to make the built design durable and waterproof.

In order to meet the Functional Specification [R51-1], it is ensured that there are no rubbing between the magnet and the solenoid. As noted in the Table 1, magnets with a diameter of 200mm are chosen. In addition there is a 0.05 cm offset between the magnet and the solenoid to minimize any possible contact. This will also ensure an increased the longevity of our design as there is minimal wear and tear.

3.3 Electrical Design

Using the Equation 1 and 2, and doing some hands-on experimentation we have formulated our electrical outputs in the Table 2.

These measurements conform to Functional Specification [R58-1] and [R59-1] as measured during the experimentation stage. The results are as follow:

Table 2: Current -Voltage Readings

	Worst Case Scenario	**Best Case Scenario**
Current (mA)	10.0*	50.0*
Voltage (V)	3.0*	6.0*

**preliminary testing show*

4 Energy Storage Unit

The ESU is connected to both EHU and EDU. It acts as a reservoir to all the energy captured or harvested by the EHU. Furthermore, it provides energy to be used by an external device via the EDU. The working of ESU is based on the following process chart shown in Figure 5.

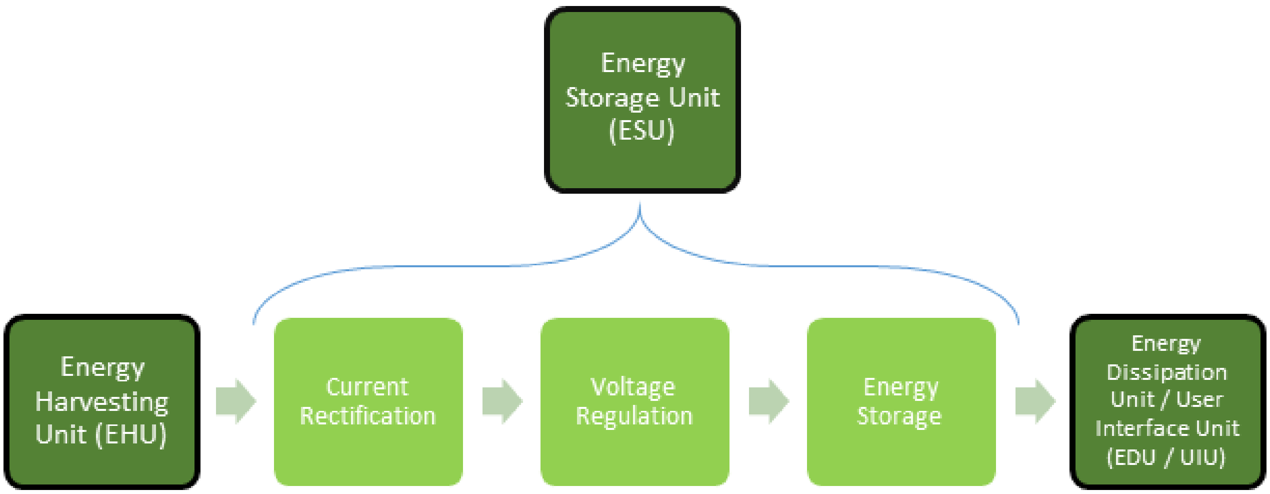


Figure 5: Energy Storage Unit Process Chart

4.1 Background

To address the functional requirement [R69-1], two main components Nokia Battery Pack and a PCB unit are used in ESU to allow the harvested energy from the EHU to be conserved in the ESU.

The PCB circuit comprises of a Bridge Rectifier and Voltage Regulator. The Bridge Rectifier converts the incoming AC current from the EHU to DC current. The converted DC current will then flow to the Voltage Regulator. The Voltage Regulator, which is a three-terminal positive regulator with a 5V fixed output voltage, provides a local regulation, internal current limiting, thermal shutdown control, and safe area protection for project. Each one of these voltage regulators can output a max current of 1.5A [3]. Using this voltage regulator in the circuit will control and limit the input to the Nokia battery pack and allows it to have a regulated input, hence safely to store the charge from the EHU.

The Nokia (DC-11) battery pack shown in Figures 6 and 7 is used as an off-the-shelf item. The Nokia (DC-11) device can be used to charge the battery in a Nokia device that has a 2.0 mm charger connector or a compatible device that has a micro-USB charger connector. It includes a power key, indicator light, 2.0mm charger connector, micro-USB charger plug, 2.0mm charger plug and weighs 96 grams [4].

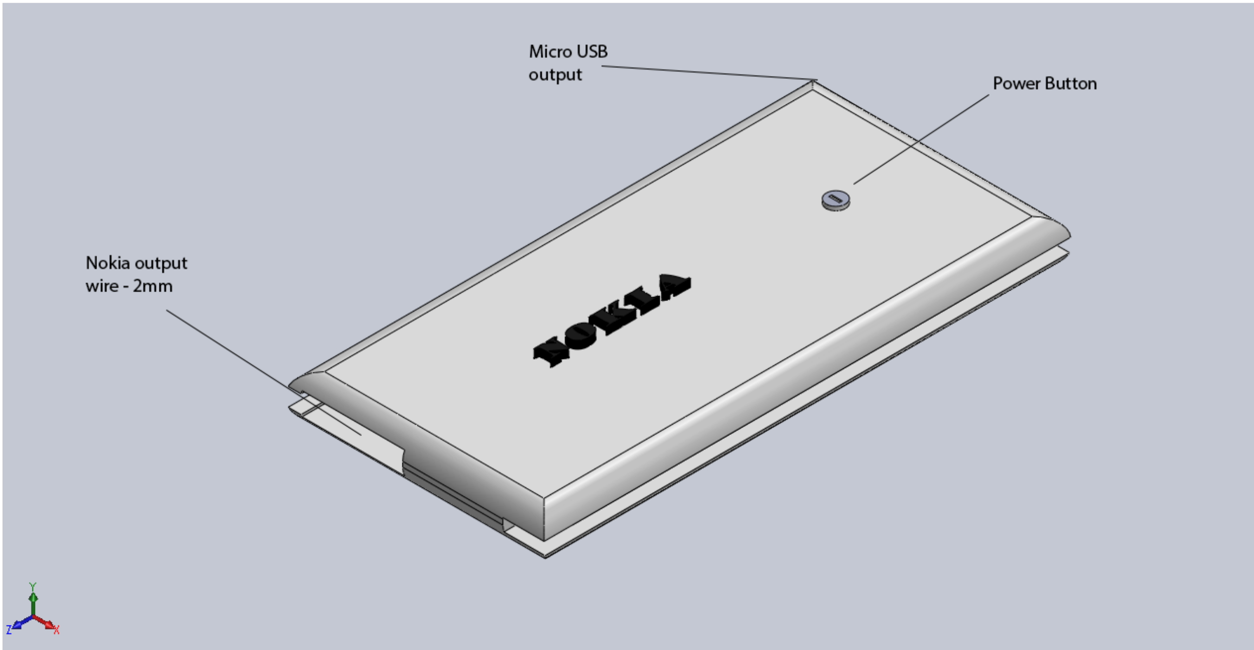


Figure 6: Isometric view of Nokia Power Pack

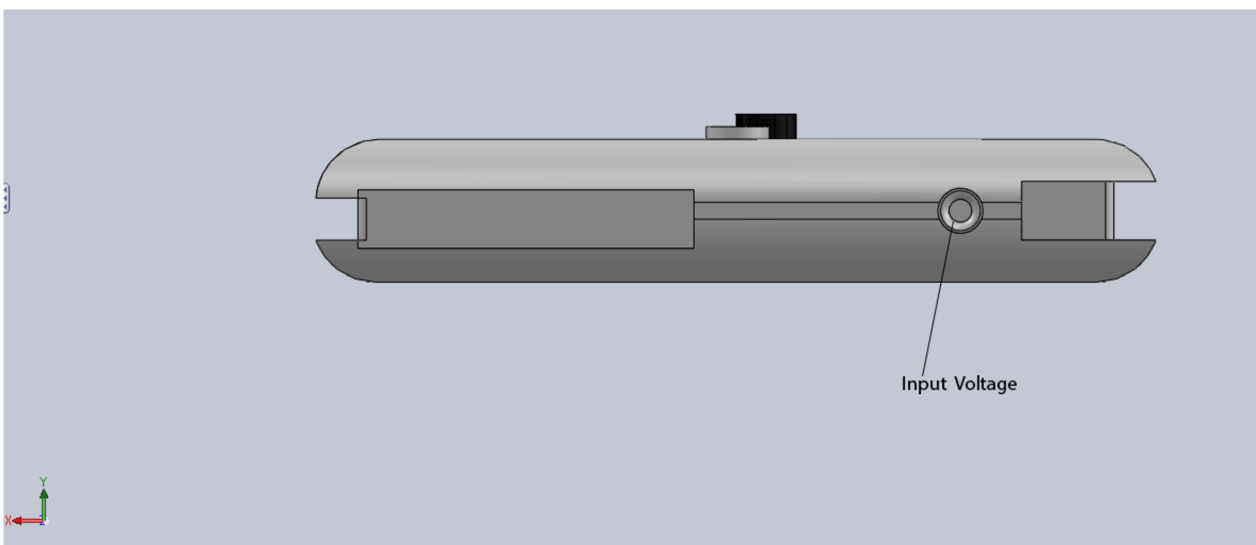


Figure 7: Side view of Nokia Power Pack

Using a battery pack eliminates the need for a complex circuit in order to safely store energy in a Li-Ion battery. Due to low cost of the device it is easily replaceable upon the time when in need. In addition, the battery pack comes in a well-insulated water and weather resistant housing and ready to be use to charge cell phone devices. This additionally eliminates the need for a cell phone battery charging protocol compatible and compliant circuit that would otherwise be required. [4]

4.2 Physical Design

All components in the ESU are chosen to be weather resistant [R5-2], water resistant [R70-2] and are rated for everyday usage [R71-2]. In order to ensure the ESU unit is electronically and environmentally insulated [R72-1], a weather resistant, waterproof [R31-1], electronically insulated [R18-2] and [R40-1] and environmentally insulated enclosure was designed and built to enclose all PCB components in the EHU. In addition, the Nokia DC-11 Battery Pack already comes in such an insulated casing from the manufacture.

To eliminate space and accessibility concerns with Nokia DC-11 Battery Pack, the pack is placed outside of the shoe in an off-the-shelf thermally insulated battery holster shown in Figure 8. Nevertheless, the Nokia DC-11 Battery Pack comes in an insulated casing [R73-1] which improves safety, durability and functionality of this unit. In a rate case in which excessive heat is generated by the battery pack the thermally insulated battery holster protects the user from any possible burns or scars.

Figure 8: Insulated Battery Holster

As shown in Figure 8, the battery pack is placed on the user's ankle and therefore away from being stepped over or being damaged by an inferior object. The ESU is designed in such that is able to withstand 250 lbs [R74-1] and 500 lbs [R75-2]. Furthermore, all ESU components including the Nokia DC-11 Battery Pack operate silently [R76-2]. The connection from the PCB to the battery pack is routed through the sole and the shoe lining as shown in Figure 9, and thus eliminates any loose wires in the unit [R77-2].

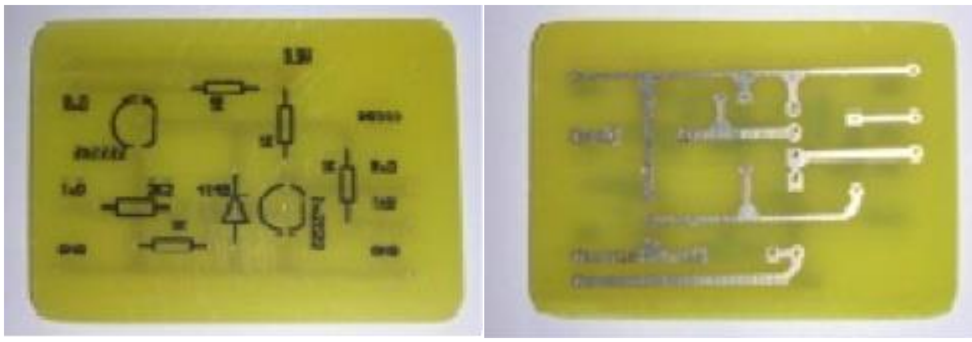


Figure 9: Sample PCB board

To further illustrate the approximate positioning of the devices, a cross section of SolexPRO is shown in Figure 10.

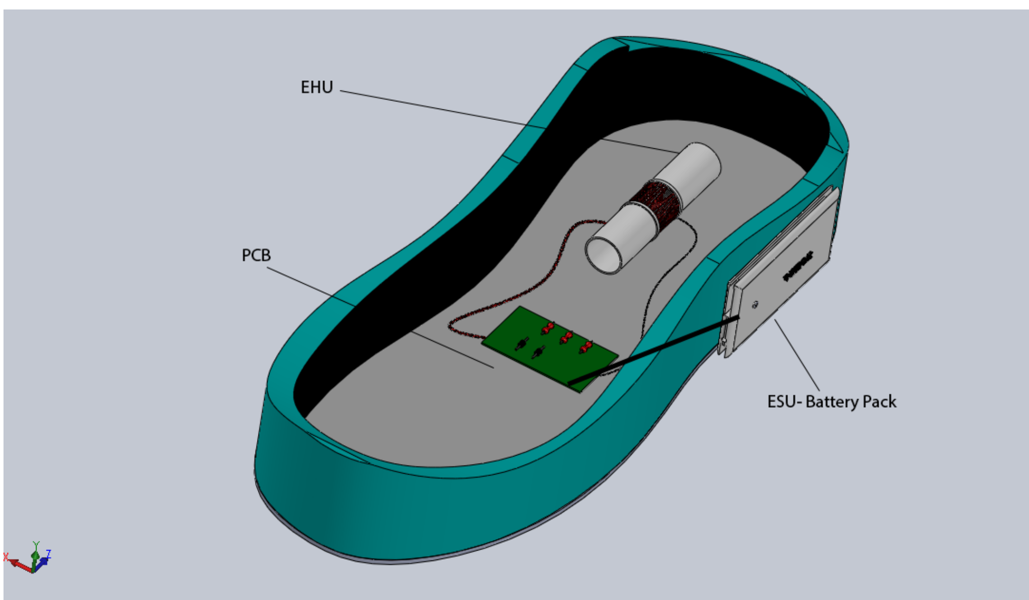


Figure 10: Sectional view of SolexPRO

4.3 Electrical Design

In order for the ESU unit to be capable of storing up to 5 V and 1.5 mA current to charge a portable device of 1500mAh rating, the Nokia DC-11 Battery Pack is chosen [R78-1]. The battery pack has been designed by its manufacturer to be able to meet the above specs [4].

The requirement of an automatic safety disconnect, in case of a current shortage, is being met by using a voltage regulator [R79-1]. The Voltage Regulator, which is a three-terminal positive regulator with a 5V fixed output voltage, provides a local regulation, internal current limiting, thermal shutdown control, and safe area protection for project. Each one of these voltage regulators can output a max current of 1.5A [3]. The schematic of the ESU electronic circuit is shown in Figure 11.

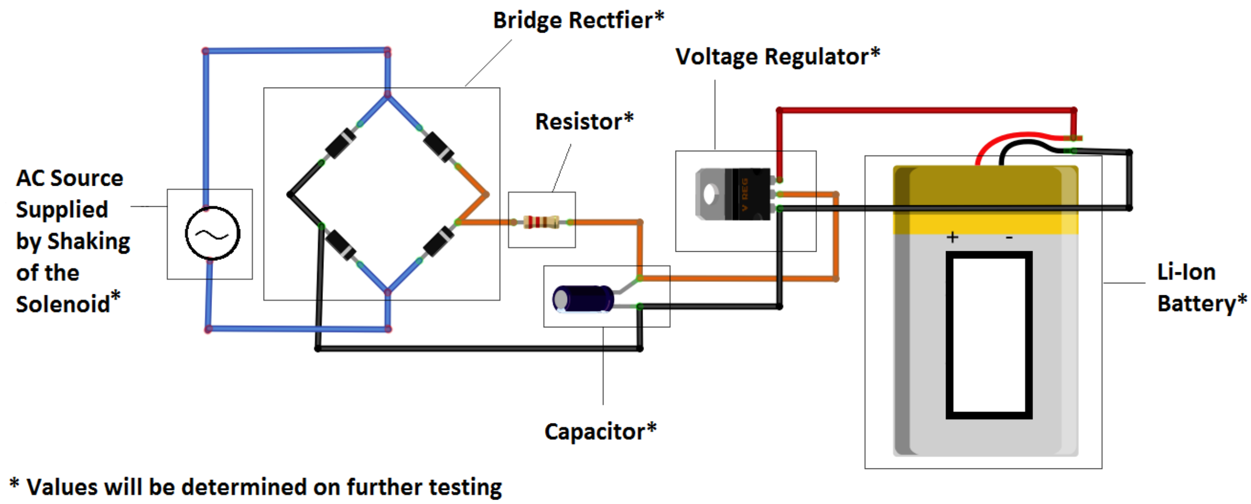


Figure 11: Schematic of the ESU Electronic Circuit

5 Energy Dissipation Unit/User Interface Unit

The EDU is responsible for allowing an external device to safely utilise the energy stored by the ESU via a UIU. The UIU shall consist of a USB port [R2-1], where electrical peripherals may be plugged in. The output from the UIU is dependent on the output from the Nokia DC-11 Battery Pack. The working of EDU/UIU is based on the following process chart shown in Figure 12.

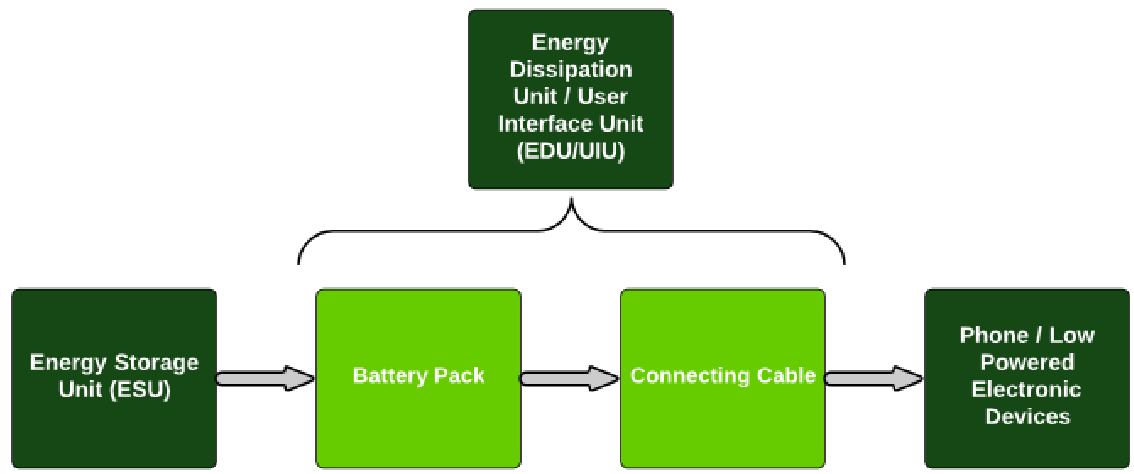


Figure 12: Energy Dissipation Unit/User Interface Unit Process Chart

5.1 Background

With the Nokia DC-11 Battery Pack, two compatible devices could be simultaneously charged. The DC-11 device can be used to charge the battery in a Nokia device that has a 2.0 mm charger connector and a compatible device that has a micro-USB charger connector [R80-1].

The Nokia DC-11 Battery Pack contains the following parts shown in Figure 13: power key (1), indicator light (2), 2.0mm charger connector (3), micro-USB charger plug (4) [R93-2] and 2.0mm charger plug (5) [R91-2].

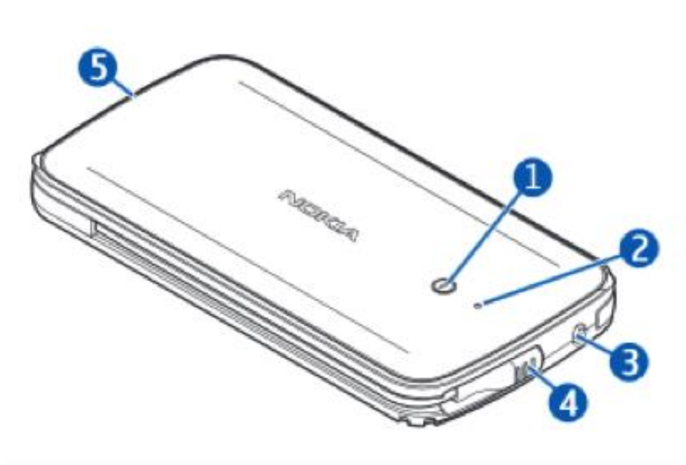


Figure 13: Nokia DC-11 Battery Pack Parts

5.2 Physical Design

The Nokia DC-11 Battery Pack shown in Figure 14 comes in a chemical leak-proof [R39-1][R29-1] weather resistant [R42-1] and waterproof casing [R81-2, R83-1]. It is also electronically and environmentally insulated, is rated commercial grade, and durable cables and ports are found along the side and ends [R82-2, R94-1]. Additionally, the battery pack does not have excessive heat dissipation [R84-1], therefore chances of the battery exploding reduces to minimum [R30-1]. Furthermore, the battery operates silently [R87-2] and has no loose wires [R88-2]

Since the battery pack is placed outside the shoe and on the ankle of the user by means of a holster, functional requirements of the EDU being able to withstand 250 lbs. and 500 lbs. of user weight is no longer be a concern [R85-1, R86-2].

Figure 14: Nokia DC-11 Battery Pack

5.3 Electrical Design

In order for the EDU unit to be capable of outputting up to 5 V and 1.5 mA current to charge a portable device of 1500mAh rating, Nokia DC-11 Power Pack is chosen as the ESU [R89-1]. The battery pack has been designed by its manufacturer to be able to meet the above specs [4]. The requirement of an automatic safety disconnect, in case of a current shortage, is being met by using a voltage regulator [R90-1]. The Voltage Regulator, which is a three-terminal positive regulator with a 5V fixed output voltage, provides a local regulation, internal current limiting, thermal shutdown control, and safe area protection for project. Each one of these voltage regulators can output a max current of 1.5A [3].

6 System Test Plan

The EHU, ESU and the EDU/UIU will be tested separately and then together to ensure reliability.

Test 1: SolexPRO Power Generation
User input: User walks at a normal gait for 15 minutes.
Measurement: A Digital Multi-Meter (DMM) that is set to measure DC Voltage is connected to the output leads of the lithium-ion battery before and after walking.
Expected observations: The DMM will read an increase in voltage from the time before walking to the time after.

Test 2: SolexPRO Vibration Resistance
User input: User jumps up and down for 10 minutes. User walks on the treadmill at level 7 for one hour.
Measurement: A visual inspection will be made to ensure that no components have become loose and/or disconnected.
Expected observations: The SolexPRO will sustain no damage.

Test 3: SolexPRO Water Resistance
User input: User walks through a puddle of water.
Measurement: A hands on inspection will confirm if the EHU remains dry or not.
Expected observations: The SolexPRO will be completely dry inside its housing.

Test 4: SolexPRO Comfort
User input: User walks, runs, jumps and does everyday activities for two days.
Measurement: User will be surveyed upon the comfort of the SolexPRO and asked if they notice any difference from regular shoes.
Expected observations: User will experience no difference from regular shoes.

Test 5: SolexPRO Noise
User input: User walks at a normal gait in a quiet room.
Measurement: A noise measuring application will measure the decibel difference of the SolexPRO versus normal shoes.
Expected observations: The decibels of the SolexPRO should not be significantly higher than normal shoes.

7 Conclusion

POWER WALKER is committed in creating an effective solution to provide renewable and portable energy. Our team is excited to develop the “SolexPRO”, a revolutionary pair of shoes that generate sustainable energy by walking and running. The design specifications for the SolexPRO and test plan have been presented in this document. The specifications are not absolute and may be modified throughout the completion of the project. POWER WALKER will use these design specifications to supply its staff with the necessary information to implement the product.

References

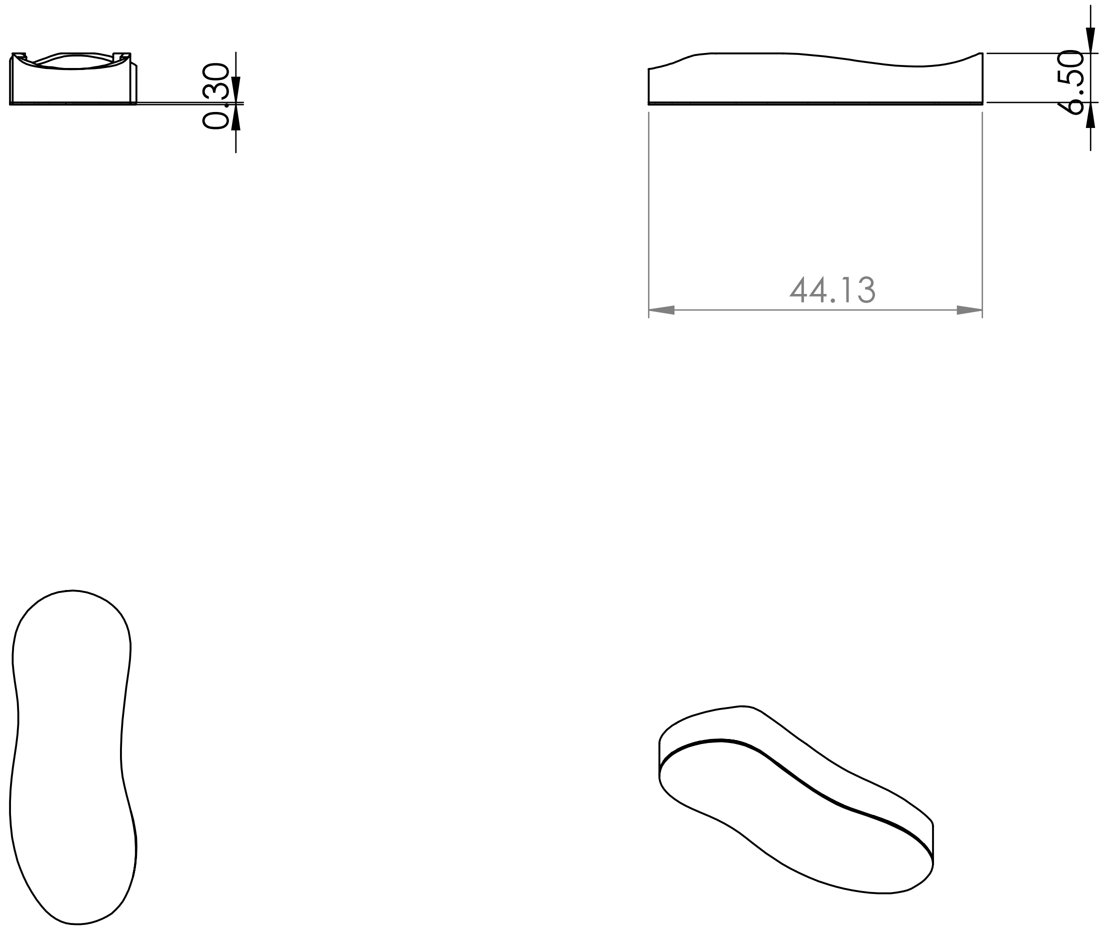
[1] "Solenoids as Magnetic Field Sources," [Online]. Available: http://hyperphysics.phy-astr.gsu.edu/hbase/magnetic/solenoid.html. [Accessed 25 February 2015].

[2] "Inductance of Coil Wires," [Online]. Available: http://hyperphysics.phy-astr.gsu.edu/hbase/magnetic/indcur.html. [Accessed 25 February 2015].

[3] Spark Fun, "Data Sheet," [Online]. Available: https://www.sparkfun.com/datasheets/Components/LM7805.pdf. [Accessed 1 March 2015].

[4] Nokia, "Nokia DC-11," 2006. [Online]. Available: http://www.herjulf.se/solar/charge-station/Nokia_2-mm_DC_Charging_Interface_Specification_v1_2_en.pdf. [Accessed 28 February 2015].

APPENDIX



Cross sectional view of the tryout pair of shoes used at PowerWalker.
Size of the shoe is 44 EUR or 10 American.

Note: Dimensions are in centimeters.

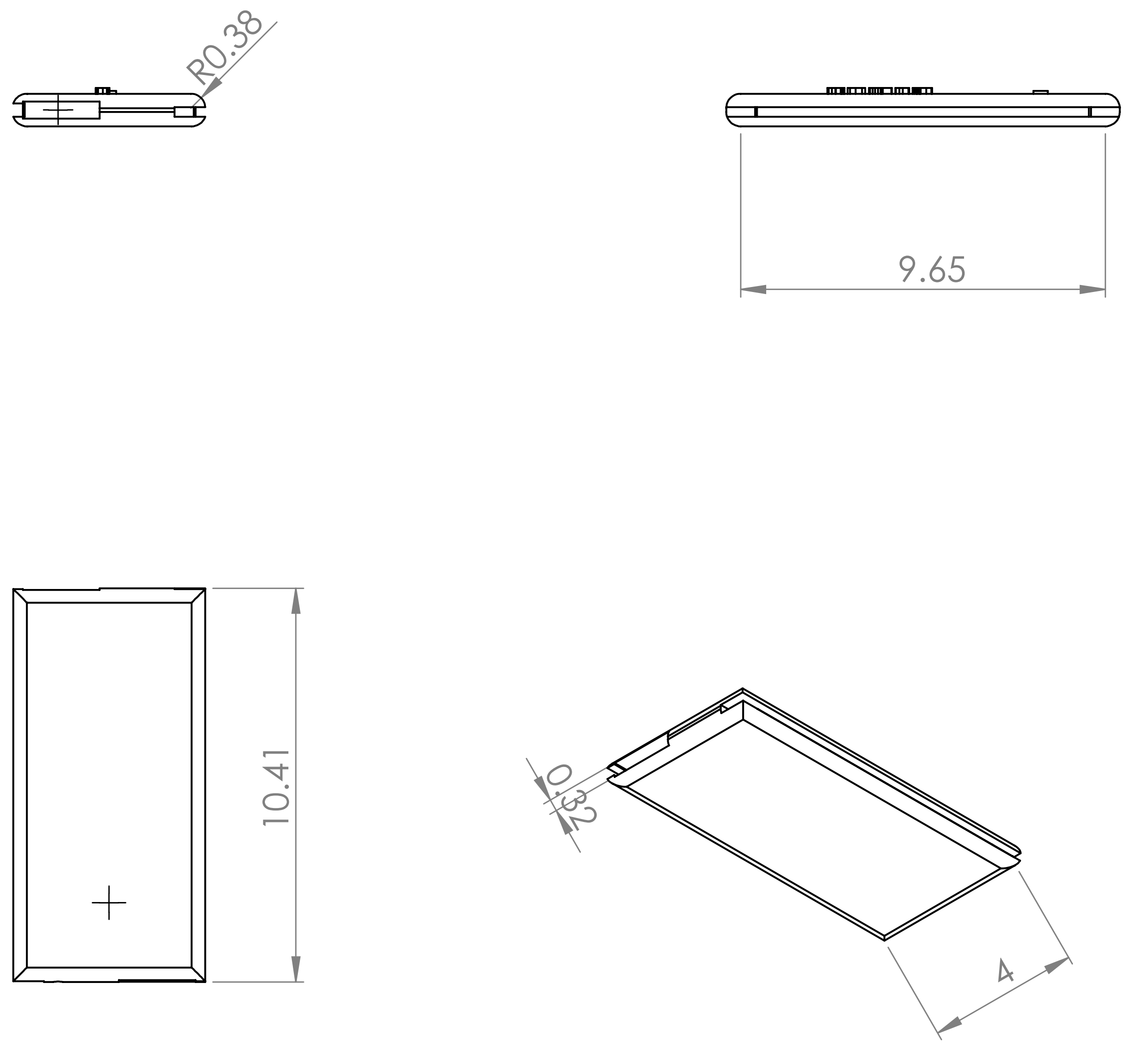
UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN Centimeters	FINISH:	DEBUR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING / REVISION C
			PowerWalker©

	NAME	SIGNATURE	DATE
DRAWN	Pouya Aein		2/3/15

TITLE: Shoe Insole Only

DWG NO. ShoePart1 A4

SCALE:1:10 SHEET 1 OF 1



Mass properties of NokiaPower battery
Configuration: Default
Coordinate system: -- default --

Density = 0.04 pounds per cubic inch
Mass = 0.09 pounds
Volume = 2.50 cubic inches
Surface area = 22.27 square inches
Center of mass: (inches)
X = 0.63
Y = 0.17
Z = 0.34

Please Note: This drawing only portrays the mechanical viewing of the power pack and does not provide any details of the interior electrical circuitry.

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH: Manufacture Default

DEBUR AND BREAK SHARP EDGES

DO NOT SCALE DRAWING

REVISION: A

PowerWalker©

	NAME
DRAWN	Pouya Aein

MATERIAL: N/A

TITLE:

Nokia Power Pack

DWG NO.

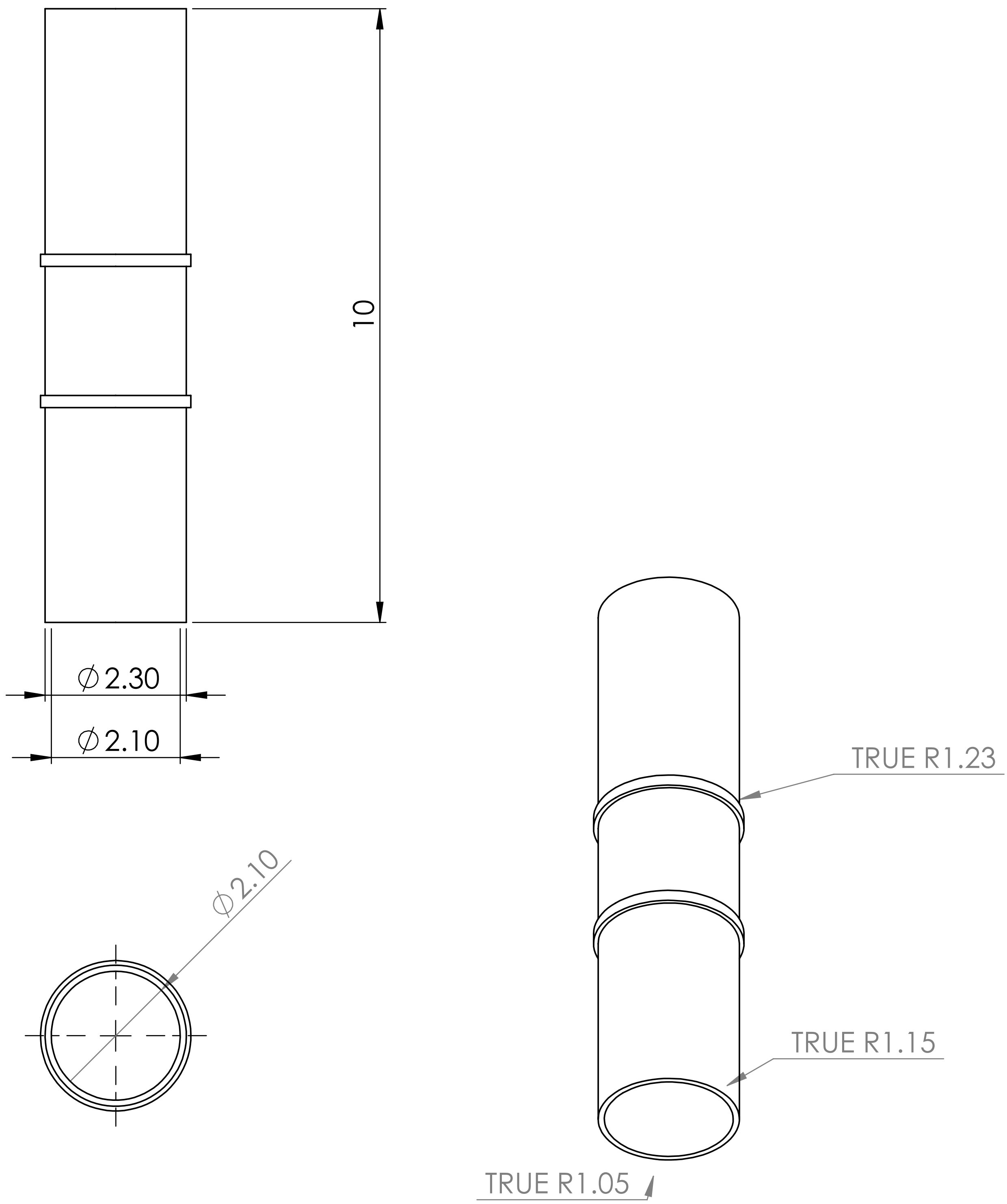
N_P_1A

A4

:

SCALE:1:2

SHEET 1 OF 1



UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN Centimeters. SURFACE FINISH:Plastic - 3Dprinted	FINISH:	DEBUR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING — REVISION D
			PowerWalker©

	NAME	SIGNATURE	DATE
DRAWN	Pouya Aein		12/3/15

TITLE:

Solenoid tube W/o Wire

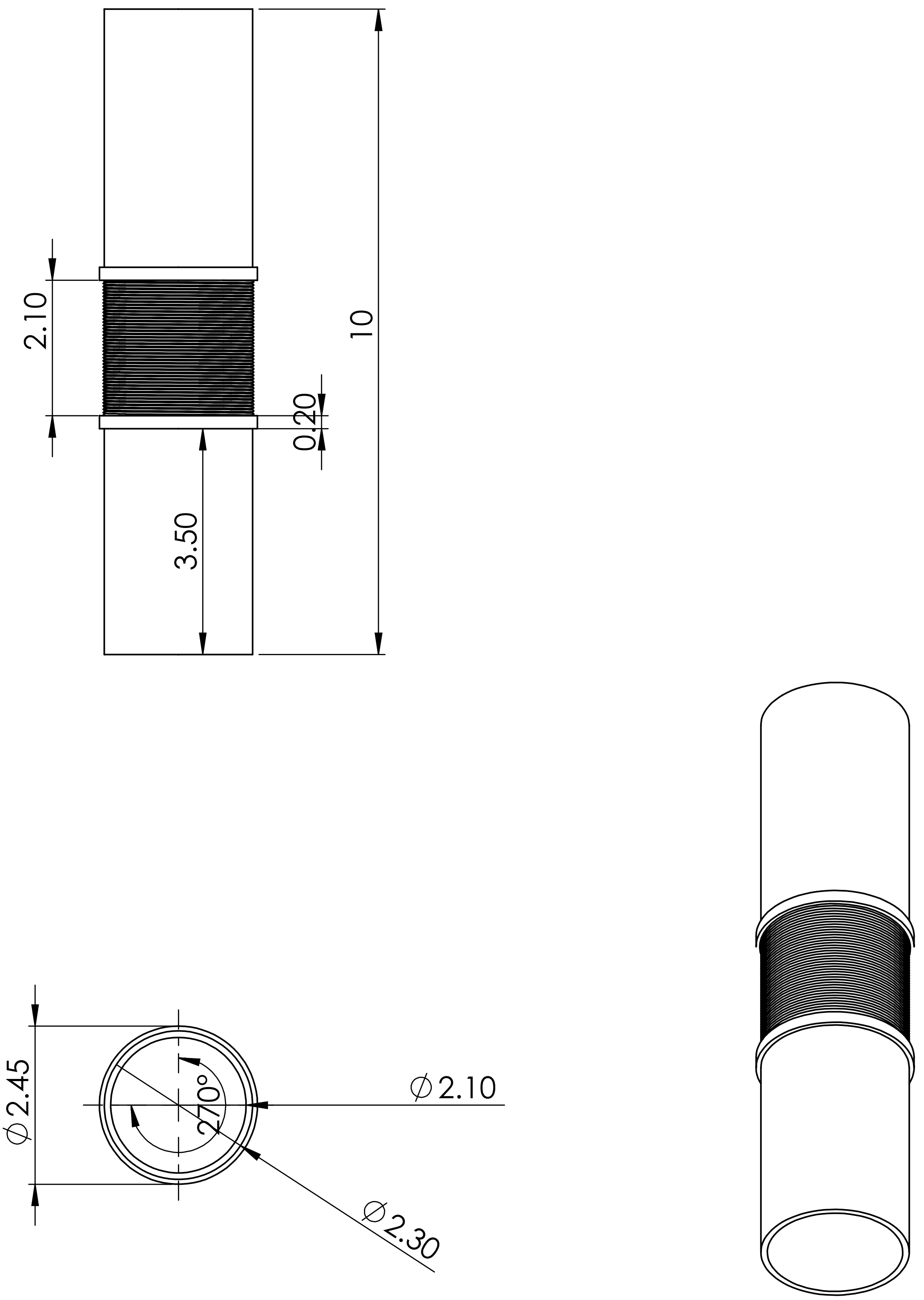
MATERIAL: 3D Print Polymer

DWG NO. S_W_t — A4

WEIGHT: 2 grams

SCALE:1:1

SHEET 1 OF 1



UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN CENTIMETERS	FINISH: 3D Print_ Plastic Polymer Copper Wire	DEBUR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING
			REVISION D
			PowerWalker©

	NAME	SIGNATURE	DATE
DRAWN	Pouya Aein		12/3/15
CHK'D	Pouya Aein		13/2/15
APPV'D	Shervin Mirsaeedi		13/3/15
MFG	SFU ENGINEERING		

TITLE: Solenoid

MATERIAL: Copper Wire

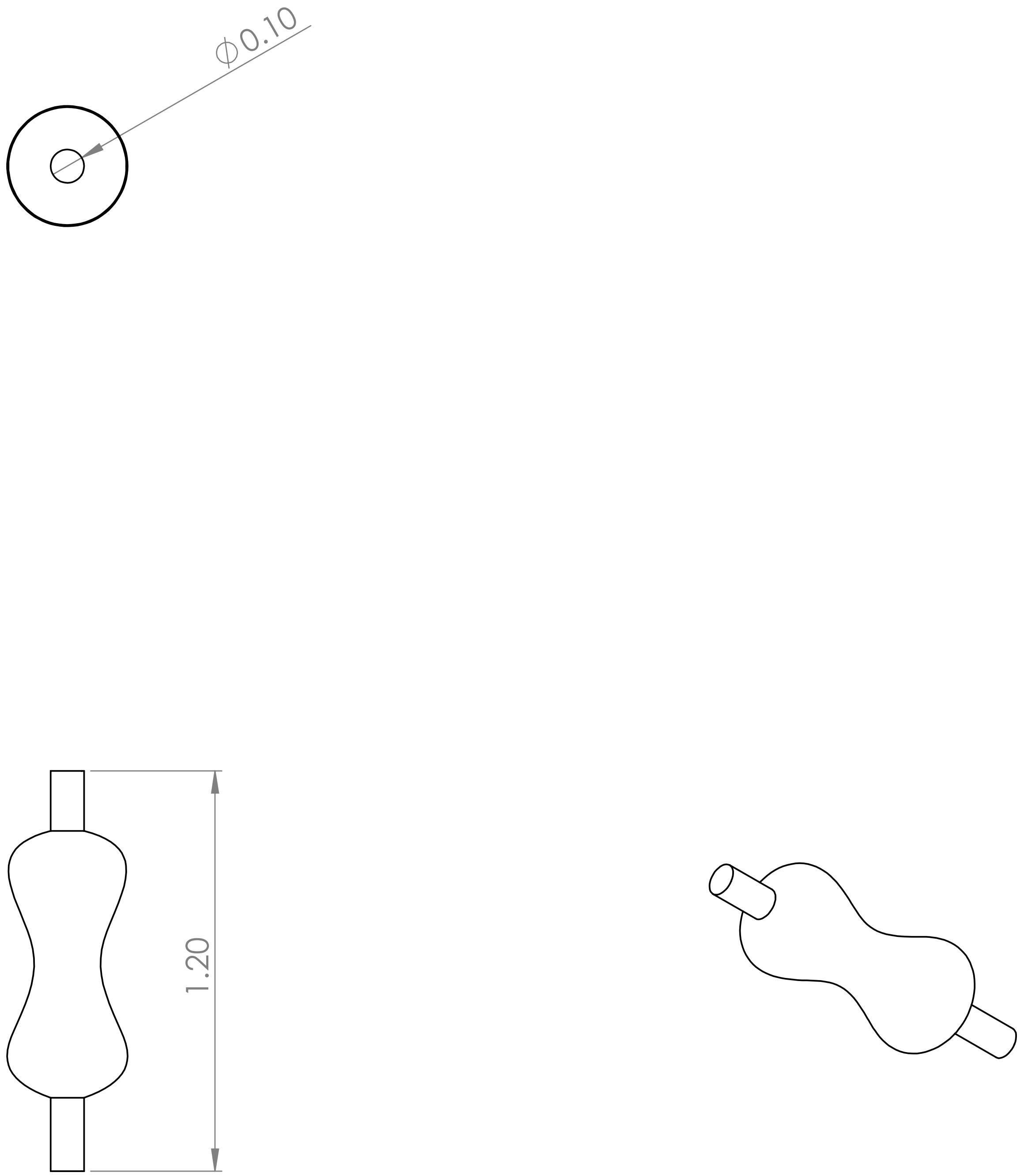
DWG NO. Solenoid

A4

SCALE:1:1

SHEET 1 OF 1

V



UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN CENTIMETERS		DEBUR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING	REVISION A

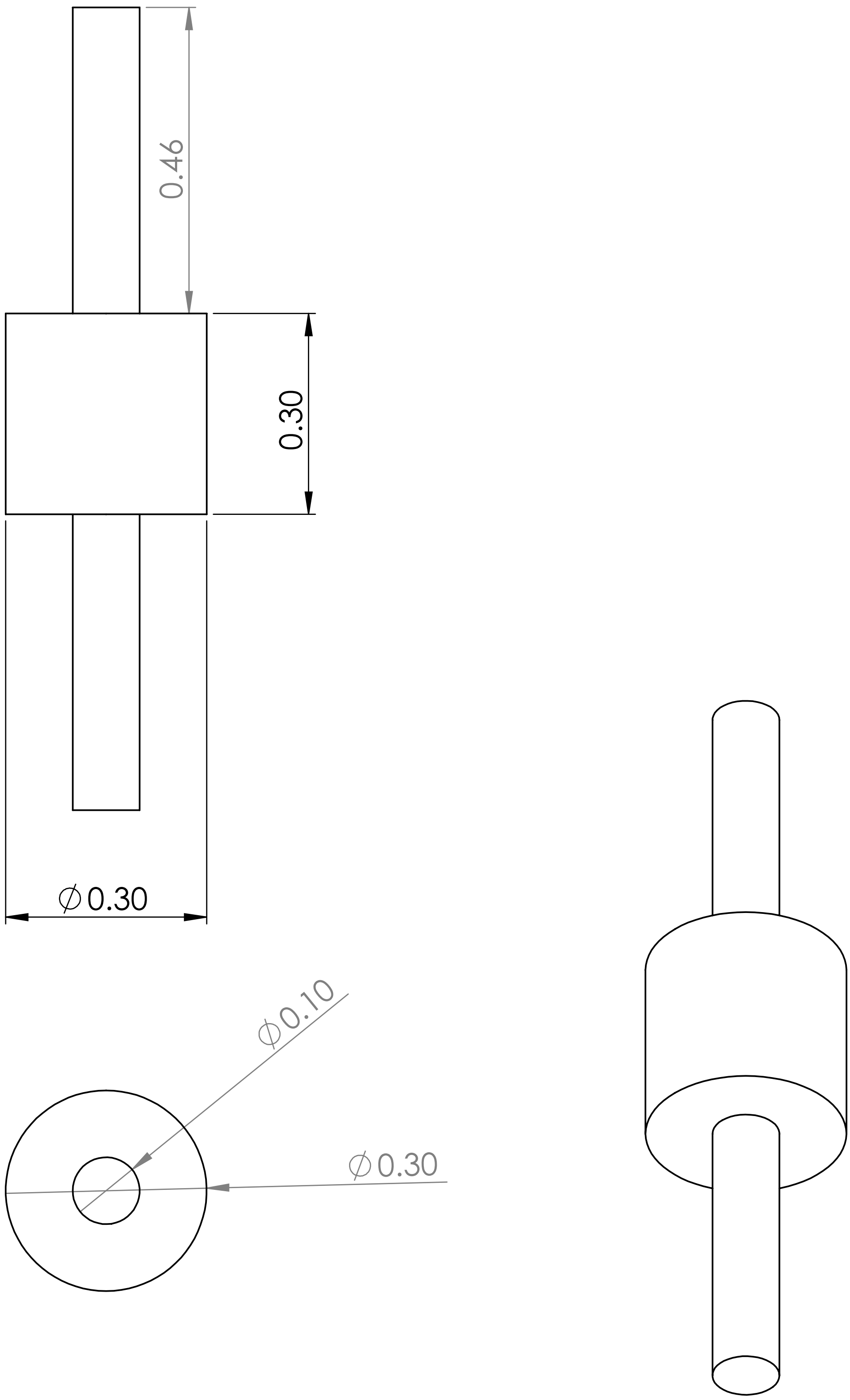
PowerWalker©

	NAME	SIGNATURE	DATE
DRAWN	Shervin Mirsaeedi		3/3/15
CHK'D	Pouya Aein		8/3/15
APPV'D	Pouya Aein		15/3/15
MFG	N/A		
Q.A	Pouya Aein		15/3/15

TITLE: Resistor

DWG NO. Resistor — A4

SCALE:5:1 — SHEET 1 OF 1



UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN CENTIMETERS

DEBUR AND BREAK SHARP EDGES

DO NOT SCALE DRAWING

REVISION A

PowerWalker©

	NAME	SIGNATURE	DATE
DRAWN	Shervin Mirsaeedi		3/3/15
CHK'D	Pouya Aein		8/3/15
APPV'D	Pouya Aein		15/3/15
MFG	N/A		
Q.A	Shervin Mirsaeedi		15/3/15

TITLE:

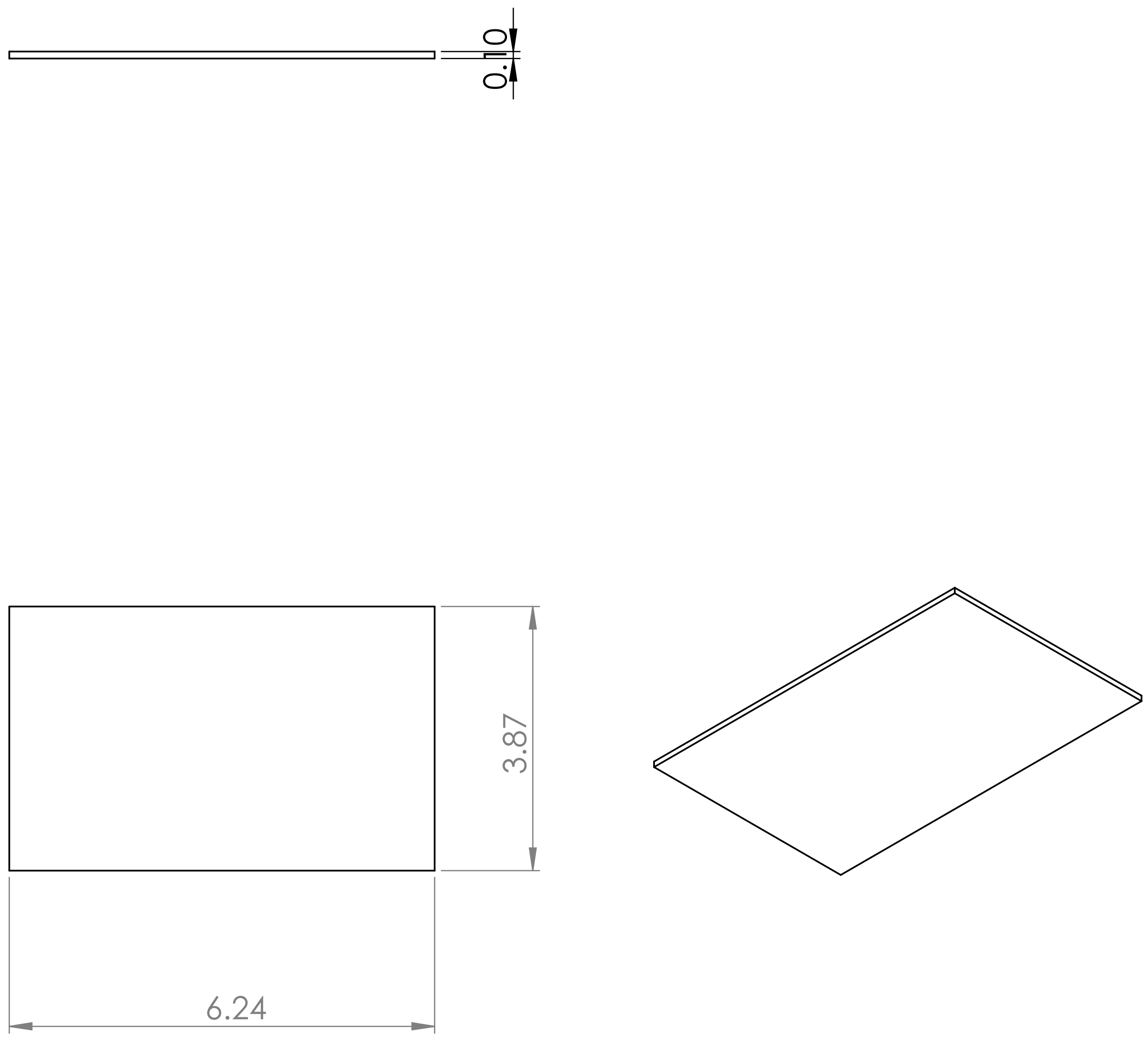
Diode

DWG NO. AssemDiode

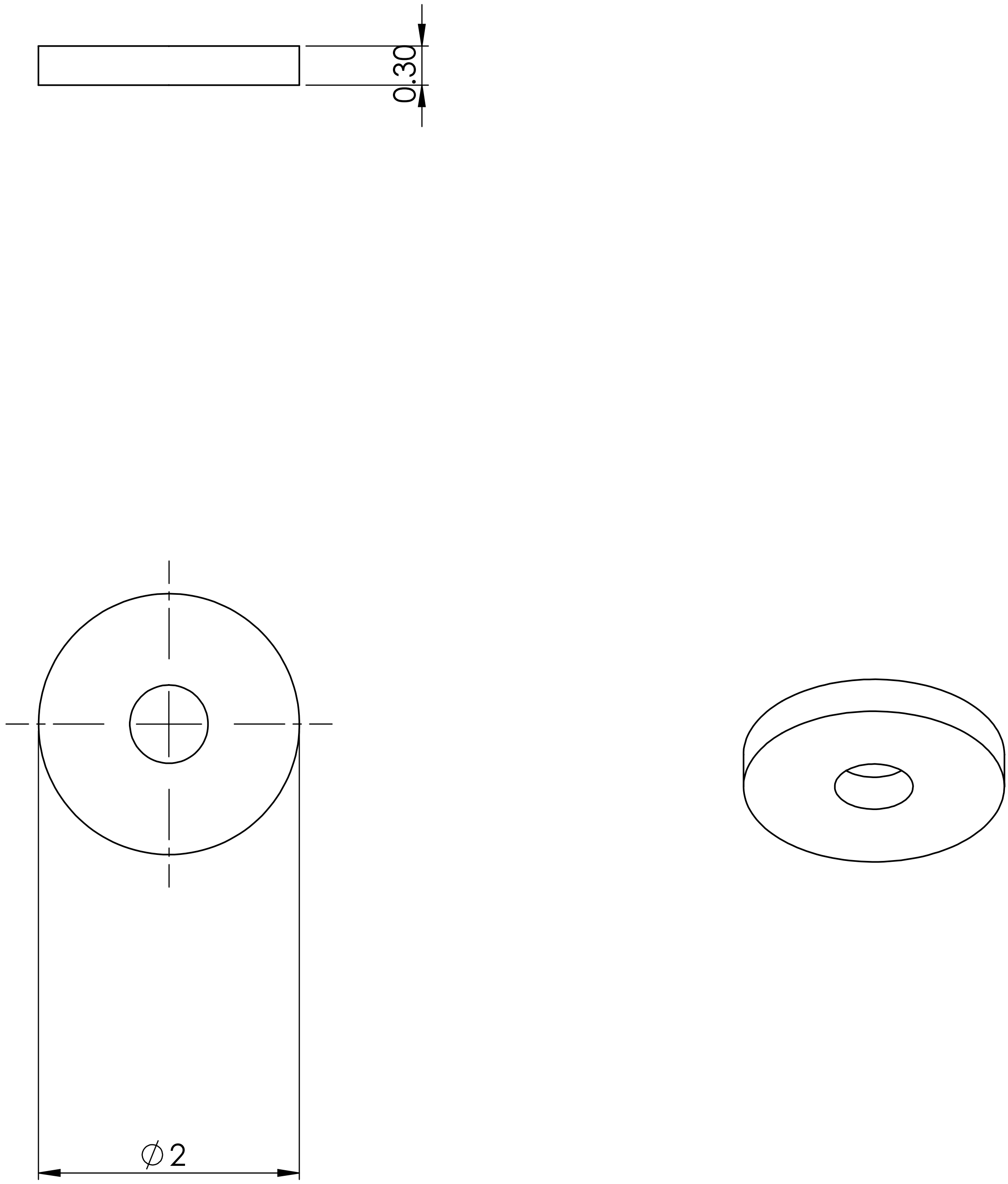
A4

SCALE:10:1

SHEET 1 OF 1



UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN CENTIMETER						DEBUR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING	REVISION A
							PowerWalker©	
	NAME	SIGNATURE	DATE				TITLE:	
DRAWN	Shervin Mirsaeedi		8/3/15				CLEAN PCB BOARD	
CHK'D	Pouya Aein		12/3/15					
APPV'D	Pouya Aein		12/3/15					
							DWG NO. CleanPCBBoard	A4
							SCALE:1:1	SHEET 1 OF 1



UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN CENTIMETERS		DEBUR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING	REVISION A
			PowerWalker©	
	NAME	SIGNATURE	DATE	TITLE:
DRAWN	Shervin Mirsaeedi		8/3/15	Magnet
CHK'D	Pouya Aein		12/3/15	
APPV'D	Pouya Aein		12/3/15	
				DWG NO. Magnet
				A4
				SCALE:2:1
				SHEET 1 OF 1